OAR Box 1824

Prepped by Charmelle Mathews

Document Number:

~~46~~ 6) IV-D-30

Docket Number:

A-90-16

Chemetals Incorporated
711 Pittman Road
Baltimore, Maryland 21226
301-789-8800

A-90-16
IV-D-30

CHEMETALS

July 18, 1990

RECEIVED
JUL 19 1990
EPA AIR DOCKET

Public Docket A-90-16
Air Docket (LE-131)
Room M-1500
U.S. Environmental Protection Agency
401 M. Street, S.W.
Washington, D.C. 20460

RE: Comment on the request of Ethyl Corporation Dated May 9, 1990 for a Fuel Additive Waiver, Clean Air Act Section 211(f)(4)

Dear Sir/Madam:

Chemetals Corporation submits these attached comments on the waiver request of Ethyl Corporation for the use of HiTEC 3000, a manganese-containing additive, in unleaded gasoline in the United States.

Chemetals has been a producer of manganese alloys and chemical derivatives for over 35 years. We are the supplier of manganese chloride to Ethyl Corporation for the manufacture of HiTEC 3000. As a long time producer of manganese fine chemicals, Chemetals is concerned about allegations made during the June 22, 1990 public hearing which inappropriately suggest that manganese used in gasoline in the form of HiTEC 3000 would present a public health problem paralleling the situation with lead.

Our comments in the attachment point out that a comparison between lead and manganese is not justified. There is a wide safety margin between the levels if normal nutritional requirements and the extremely high levels where neurotoxicity becomes a concern. The use of HiTEC 3000 does not cause a shift in the current ambient levels of manganese in our environment to those levels where neurotoxicity becomes a concern.

In view of our comments in the attachment, we strongly urge your favorable action on the Ethyl Corporation waiver request for the use of HiTEC 3000 in unleaded gasoline in the U.S.

Very truly yours,

Dr. Francis J. Keenan
Director-Research & Development

Dr. Denis F. DeCraene
Director-Business Development

enclosures

cc: Mary T. Smith
Director-Field Operations
and Support Division
(EN-397F)

DFD:mrt

RECEIVED
JUL 19 1990
EPA AIR DOCKET

STATEMENT OF CHEMETALS CORPORATION IN SUPPORT OF ETHYL CORPORATION'S HiTEC 3000 WAIVER REQUEST

I. INTRODUCTION

Chemetals is a world leader in the production of manganese fine chemicals. Headquartered in Baltimore, MD, Chemetals has production facilities in Baltimore, MD and New Johnsonville, TN, and sales offices in Baltimore, MD, Pittsburgh, PA, and Brussels, BELGIUM.

Chemetals, together with Sedema S.A. headquartered in Tertre, BELGIUM (a sister company), has been manufacturing manganese derivatives for over 35 years. Our products are sold to the Agriculture, Aluminum, Battery, Catalyst, Ceramics, Electronics, Magnesium, Petroleum Refining, Steel, Water Treatment, and Welding Industries. Chemetals and Sedema market and sell their products in these industries in U.S., Europe, the Far East as well as in underdeveloped countries.

As a major producer of manganese fine chemicals, Chemetals supplies manganese chemicals to Ethyl Corporation for the production of HiTEC 3000.

II. CHEMETALS SUPPORTS THE ETHYL WAIVER REQUEST

Chemetals believes Ethyl's additive is beneficial because it reduces overall toxic emissions to the atmosphere both from the tailpipe and at the refinery, while offering options to the refiner for meeting the demands of the transportation fuel market and making a favorable impact upon the balance of trade.

We have reviewed the waiver request and find that HiTEC 3000 has benefits in terms of the auto tailpipe emissions:

1) Unburned hydrocarbons are increased slightly at the tailpipe. However they remain well below the current standard of 0.41 gm/mile and even approach the proposed standard of 0.26 gm/mile. In the test, HiTEC 3000 raised the octane level of the Mn-containing gasoline by 0.9 octane numbers. When unleaded gasoline is formulated to a given octane level, the refiner can use less of the other octane producing aromatic components to reduce tailpipe HC emissions, as well as fuel volatility.

2) CO emissions are reduced by an average of 0.22 gm/mile.

3) NO_X emissions are reduced by 0.11 gm/mile. This effect substantially enhances the ability to achieve the proposed NO_X standard.

4) Total emissions are reduced by 16%.

We also find that the data demonstrate no adverse effects upon the emission control systems.

III. CHEMETALS IS CONCERNED THAT MANGANESE NOT BE MISCHARACTERIZED AS A PUBLIC HEALTH CONCERN

As a major worldwide manganese producer, Chemetals is a member of the International Manganese Institute, Paris, FRANCE. This organization is composed of 40 member companies including most of the Free World producers of manganese ore, metal, alloys, and chemicals. The Manganese Institute is extremely conscious of the health issues relating to manganese in occupational and environmental settings. To that end, the Institute runs a committee on occupational health and the environment. This committee has the charter of preparing guidelines to educate producers and users about the appropriate ways to use and dispose of manganese derivatives in their respective applications. As a member of this group, Chemetals is concerned about the mischaracterization of manganese as a cause for health concerns in the testimony at the EPA Public Hearing on the Ethyl waiver request.

The hearing testimony was focused upon the potential effects of exposure to manganese at extreme levels and gave a skewed perspective of manganese compared to the real, overall picture.

On the contrary, manganese is an essential element to human health. Manganese plays a key role in:

a) Formation of connective tissue and bone.
b) Growth.
c) Carbohydrate and lipid metabolism.
d) Embryonic development of the inner ear.
e) Embryonic development of the reproductive function.

As the testimony at the hearing pointed out, neurotoxicity concerns develop at very high levels. However, these levels are greatly above the current normal levels arising from natural and manmade emissions. Further, the Ethyl data show clearly that the use of **HiTEC 3000 does not cause incremental manganese emissions approaching these higher risk levels.**

IV. HOW EPA SHOULD ADDRESS THE QUESTION OF THE HEALTH EFFECTS OF MANGANESE IN THIS PROCEEDING

In exercising its discretion under SECTION 211 (f)(4) of the Clean Air Act, EPA must consider whether Ethyl has met its burden of demonstrating that the fuel additive (HiTEC 3000) and its emission products will not cause or contribute to a failure of any emission control device or system over the life of the vehicle to achieve compliance with the emission standard for which the vehicle is certified. Ethyl has met this burden.

The Environmental Defense Fund seeks to add two additional burdens that the Clean Air Act does not impose on the applicant for such a waiver. The Clean Air Act does not, as the EDF suggests, require the waiver applicant to prove that the additive will not affect human health or add measurably to environmental loadings of a constituent.

EPA is charged by Congress to act responsibly in exercising its duties, and its actions are properly judged in terms of the public health and welfare. Therefore, the agency may properly consider the question of manganese and its health and environmental effects. However, the base from which these considerations proceed is the currently known data on manganese. Manganese has been studied for many years, and there is a body of data that discusses what is known and unknown about its health effects. An objective review of data will satisfy the responsibility of the waiver applicant.

Reviewed objectively, these data demonstrate that EPA would act responsibly in granting the waiver for HiTEC 3000, because the incremental release of manganese to the environment, given the known health risks, does not justify a concern.

V. MANGANESE DOES NOT POSE A PUBLIC HEALTH RISK

A. MANGANESE IS ESSENTIAL TO GOOD HEALTH

Manganese is a biologially active element which is essential to good health. Deficiencies in manganese can cause disturbances in many biological processes. While its specific functions are not precisely defined, manganese plays a key role in:

Growth
Metabolism
Embryonic Development of the Inner Ear and the Reproductive Function

While the minimum daily nutritional requirement for manganese has not been precisely established, normal daily oral intake provides about 2,400 µg/day in adults. People take vitamins to assure that they receive the needed levels of vitamins and minerals, including manganese.

B. THE AVERAGE DAILY MANGANESE UPTAKE OF THE HUMAN BODY IS NOT AFFECTED BY THE USE OF HiTEC 3000 IN GASOLINE

The human body has natural mechanisms for using the manganese it needs and readily disposing of the manganese it does not. The data on manganese in the body show an excellent homeostasis in terms of manganese in concentrations well above the average daily intake. An average man, weighing 70 Kg (approx. 155 lbs.) has about 12,000 µg manganese in his entire body. Concentrations of manganese in the body do not change with age. While the average intake is 2,400 µg/day, daily intake can range from 500 µg/day up to 8,000 µg/day.

Assuming, conservatively, an average inhalation rate of 20 m^3/day of air, and an incremental peak increase of 0.0009 μg/m^3 of manganese in urban areas such as Philadelphia as a result of the use of HiTEC 3000 in unleaded gasoline, incremental increase in manganese intake from the use of HiTEC 3000 would be 0.018 μg/day. **This would be no material increase in the average daily uptake and well within the normal daily range.**

C. MANGANESE IS NOT CARCINOGENIC

Manganese is not a known carcinogen. There are no known data indicating carcinogenicity. The 1984 EPA Health Assessment Document concluded that Mn would be rated Group III using criteria established by the International Agency for Research on Cancer (IARC). Some research indicates that manganese plays an inhibiting role in tumor development and growth.

D. THE USE OF HiTEC 3000 DOES NOT CAUSE EXPOSURE TO MANGANESE AT LEVELS THAT RISK NEUROTOXICITY OR OTHER HEALTH EFFECTS

The neurotoxic effects of manganese occur only at extremely high levels. There is no arguement that high concentrations of manganese can produce neurological disorders resembling Parkinsonism and may have acute effects on the lungs. What must be clearly pointed out is that there is a wide margin between the minimal nutritional requirements for good health and the levels at which toxicity occurs.

Neurological disorders have only been observed in individuals with massive occupational exposures. All verified cases have resulted from the prolonged inhalation of dusts containing in excess of 2,000-5,000 μg/M^3 in occupational settings.

OSHA has set an air concentration limit for worker exposure to manganese that is 20,000X above ambient concentrations. The OSHA standard is 5,000 μg/M^3 for Mn dust. This standard is based on the original recommendation of the American Conference of Governmental Industrial Hygienists as a ceiling limit for manganese exposure. More recently, this widely respected group has relaxed its recommendation to a time-weighted-average (TWA) level of 5,000 μg/M^3.

The EPA has evaluated the health effects of airborne manganese and has identified no health effects at levels below 300 μg/M^3 (HAD 1984). This is 1000 times higher than current ambient levels.

Ambient levels in urban environments with point sources of manganese are in the range of 0.2 - 0.3 μg/M^3, or about 1/20,000 the OSHA standard. The Ethyl data shows that manganese emissions from the use of HiTEC 3000 in gasoline would cause an incremental increase of 0.0009 μg/M^3

in ambient manganese levels in an urban area such as Philadelphia. As shown in the following Table this would have no material impact on the ambient levels in terms of the OSHA ceiling limit, nor does it materially shift ambient levels any closer to the "safe" level as deemed by EPA.

TABLE: Comparison of Airbourne Manganese Levels Through Use of HiTEC 3000: Ambient Urban Levels vs. Levels Causing Documented Health Effects

	Mn Levels Current ($\mu g/m^3$)	**Mn Levels if HiTEC 3000 Wavier Granted ($\mu g/m^3$)**
Urban Areas with Point Source	0.2-0.3	0.2009-0.3009
Urban Areas in U.S., Average	0.095	0.0959
OSHA Standard	5000	-
Lowest Observed Adverse Neurological Effects Level	2000	-
Lowest Observed Adverse Health Effects Level	300	-

E. MANGANESE IS NOT A TOXIC METAL LIKE LEAD

There are vast differences between the effects of manganese and lead on the human body. Manganese is essential to the mitochondrial function and for carbohydrate metabolism. Lead has no known benefits to the body's homeostasis. Lead can show numerous acute toxicological symptoms, including encephalopathy, as a result of low levels of exposure. Only at extremely high doses for protracted periods of time does manganese have the potential to do damage to the body. OSHA has set worker exposure limits for lead are 50 $\mu g/m^3$ as compared to manganese limits at 5,000 $\mu g/m^3$ (100X higher). NIOSH states that lead compounds may be IDLH (Immediately Dangerous to Life & Health) at concentrations of 300,000 $\mu g/m^3$ while manganese is listed as IDLH at 10,000,000 $\mu g/m^3$, a vast difference. The Food and Drug Administration has designated manganese compounds, such as manganese chloride, manganese sulfate, manganese gluconate and manganese citrate as "Generally Recognized as Safe" for use as direct human food ingredients. See 21 CFR 184.446 _et seq_. No lead compounds are so recognized by FDA.

VI. THE ADDITION OF MANGANESE TO THE ENVIRONMENT FROM MMT IN FUEL WOULD HAVE NO ADVERSE IMPACT

A. MANGANESE IS A SIGNIFICANT GLOBAL ENVIRONMENTAL CONSTITUENT

Manganese is ubiquitous and is produced in vast quantities, in comparison to which the amount of manganese added to the environment by the use of HiTEC 3000 would be insignificant.

Manganese is universally present in the environment. Manganese is the twelfth most common element and fifth most common metal in the earth's crust. It is widely distributed in over 300 mineral species of sedimentary and igneous rock. Manganese is also a minor constituent of all coal ash. Mn is present at low levels in nearly all forms of matter: air, water, and land.

Studies have indicated that the ambient air levels of Mn vary widely from remote areas to industrialized urban areas. The value depends heavily on human activity as well as natural meteorological and volcanic activity, etc. In 1982, for urban areas in Canada and the U.S., the average level of ambient manganese values ranged from 0.065-0.095 $\mu g/m^3$, respectively. Areas with point source emitters typically ranges from 0.2-0.3 $\mu g/m^3$. Studies show that on a worldwide basis, an estimated 610 million kilograms/year of manganese are emitted into the atmosphere from natural sources compared with 320 million kilograms/year resulting from human activities. These data show that manganese is a significant presence in the air we breathe.

Manganese is present in nearly all sources of surface and subsurface water. Due to weathering of rocks and minerals, manganese is constantly being introduced into the water supplies from natural sources. Due to the action of microbes and other factors, manganese can be either oxidized or reduced. If manganese is oxidized, the soluble manganese level will drop. If manganese is reduced the concentration will increase. Numerous studies have described the transport mechanisms of manganese in such environment. Their studies have shown that average manganese concentrations range from 2.3-232 µg/l for 16 drainage basins in the U.S. In general, manganese levels are higher in subsurface water supplies. The available data show that manganese is commonly present in our environment.

As stated previously, manganese is widely distributed in mineral species. According to one study the level of manganese is:

1,000 µg/g	earth crust
2,000 µg/g	basic rocks
600 µg/g	acid rocks
670 µg/g	sedimentary rocks
850 µg/g	soils

These levels show that manganese is naturally present in dusts and soils. This substantial natural presence is the reason that natural emissions are almost twice as high as emissions due to human activities involving manganese.

The use of HiTEC 3000 will not significantly increase production of manganese. The worldwide production of manganese ore in 1987 was over 25 million tons or about 9 million tons of manganese. The large majority (80-90%) of manganese is used in the production of iron and steel. Manganese is used both to control the level of impurities in steel and as an alloying agent for numerous grades of steel. As such, nearly all the iron and steel produced annually contains up to 1% manganese.

Manganese is also essential for many other activities such as agriculture, non-ferrous metallurgy, electronic materials manufacture, catalysis, primary batteries, glass making, and water purification. Manganese is intertwined in many of the goods and processes that constitute our civilized society.

In comparison to all other known uses HiTEC 3000 would be a very small consumer of manganese. Using the extreme case, if every gallon of gasoline in the U.S. contained the proposed concentration of .03125 g manganese as HiTEC 3000, then 3,450 tons/year of manganese would be consumed. This represents less than 0.04% of the worldwide production.

The current ambient levels of manganese present in the environment due to natural as well as manmade emission are 10-100X higher than the incremental contribution of manganese resulting from the use of HiTEC 3000 in gasoline. **The use of HiTEC 3000 gasoline will have no impact on the distribution or loadings of manganese in the environment resulting from manmade emissions.**

B. THE INTRODUCTION OF MANGANESE TO THE AIR FROM THE USE OF HiTEC 3000 WOULD BE INSIGNIFICANT

One study reported the average ambient manganese concentration in U.S. urban locations to be 0.095 $\mu g/M^3$ where there were no point sources. Urban areas where there are point sources exhibit ambient manganese levels an order of magnitude higher, i.e. in the range of 0.2-0.3 $\mu g/m^3$. Other studies have shown the ambient values correlate with the level of human activity and proximity to point source emitters. In 1981, the World Health Organization (WHO) stated conclusively that there is no evidence of any health risk to humans resulting from ambient manganese levels in urban environments.

Ethyl has used EPA protocol to measure the particulate emissions from cars fueled with gasoline containing HiTEC 3000. On average, only 0.4% of the contained manganese exited the tailpipe. Ethyl has shown in their waiver request that the use of HiTEC 3000 in urban areas (such as Philadelphia) will result in a peak concentration increase of 0.0009 $\mu g/M^3$. This represents a 1-5 percent increase in current ambient levels assuming that 100% of the manganese which exits the tailpipe reports in the air. **Therefore, it is clear the use of HiTEC 3000 will not contribute a significant amount of manganese to current ambient levels.**

C. THE ADDITION OF MANGANESE TO THE SOIL WOULD BE INSIGNIFICANT

Ultimately, all airbourne manganese is deposited on water or soils. As stated above, soils contain an average of 850 µg/g of manganese. The use of HiTEC 3000 will not impact this value since **natural deposition rates overwhelm those due to HiTEC 3000.** Using data found in Ethyl's waiver request, the Philadelphia urban area represents 30,625 Km^2. Assuming 3.4 X 10^6 cars drive 12,000 miles per year and achieve 25 miles/gal fuel economy, there would be 1.632 X 10^9 gallons of fuel consumed. If each gallon contained 0.03125 g of manganese and 0.4% of this manganese was emitted from the tailpipe, then 204,000 g of manganese would be emitted as manganese oxides. The would result in a deposition rate of 6.7 $\mu g/M^2$-Yr of manganese assuming that 100% of the manganese emitted from the tailpipe finally reports to the soil. When one compares this to published values for New York City in 1975, which is a dry deposition rate of 36,000-80,400 $\mu g/M^2$-Yr, contributions from HiTEC 3000 would represent less than 0.02 percent increased manganese; no material change.

D. THE ADDITION OF MANGANESE TO WATER WOULD NOT POSE A PROBLEM

Manganese is a natural constituent of most surface and subsurface water supplies. A very significant amount of this total results from weathering and acid drainage of manganese containing minerals. Other sources include atmospheric dusts which subsequently dissolve or are reduced by organics or microbes.

The EPA drinking water standard for manganese is 50 µg/l. This value was set on the basis of aesthetics and not on any perceived public health hazard. Many subsurface water supplies naturally have levels much higher than this value. In the case of drinking water, manganese is easily removed by the conventional treatment techniques practiced by water treatment facilities.

The fate of manganese in surface water has been studied extensively. In most surface water systems, dissolved manganese is quickly oxidized and precipitated to become part of the sediment. However, in the case of acidic lakes (pH <5), manganese levels would be higher than non-acidic lakes and streams. One study estimated that 4 X 10^{10} Kg/Yr of manganese enter the riverine environment on a worldwide basis. If HiTEC 3000 is used in every gallon of fuel consumed in the U.S., a maximum of 12,500 Kg of manganese/gr would enter these bodies of water via deposited dusts. Clearly, the use of HiTEC 3000 will have no material impact on current values.

E. THE USE OF HiTEC 3000 DOES NOT CREATE A SOLID WASTE DISPOSAL PROBLEM IN SCRAPPED AUTOMOBILES

The average 1989 automobile weighs 3,140 lbs. and contains 1,728 lbs. of steel. Taking into account the different types of steel used in automobiles, the average automobile contains 7.63 lbs. of manganese in the form of steel alloy. In 1989 the auto industry in the U.S. produced 6,833,097 cars. These cars contained a total of 52,136,530 lbs. of manganese (26,068 tons). There are no solid statistics on the rate of recycle for the steel from scrap automobiles. However, it is reasonable to assume that approximately 85% of this steel finds its way back into the market in some way or another. This would leave only 15% of the steel as an additional load on the environment. This calculates to 7,820,498 lbs. (3,910 tons) of manganese.

The average automobile has a lifetime of 7.6 years. During that period, that car will be driven an average of 12,000 miles per year and have an average fuel economy of 25 miles per gallon. At a fuel concentration of 0.03125 gm manganese per gallon, a total of 114 gm of manganese will be introduced into the engine and exhaust system of the car. Since only 0.4% of that manganese will exit the tailpipe, 113.5 gm (0.25 lbs.) will remain in the car to be scrapped at the end of its useful life. This represents a 3% increase in the manganese content of the scrap automobile and does not impose an unmanageable additional load on the environment.

The fate of most scrapped automobiles today is recycling. Approximately 85% of all automobiles are crushed and recycled for their steel, of which manganese is a necessary ingredient. The remaining 15% are disposed of as solid waste. The manganese content of scrapped automobiles is not regarded by RCRA as a hazard. No waste has been designated by RCRA regulations as hazardous, nor is manganese regarded as a hazardous constituent of solid waste.

VII. CONCLUSION

Chemetals finds that the use of HiTEC 3000 in gasoline causes no technical problems with the emission control systems, enhances efforts to preserve the quality of the environment by reducing total tailpipe emission, and adds flexibility to the Petroleum Refining Industry while also having a favorable impact on U.S. balance of trade.

The use of HiTEC 3000 in gasoline will not create a public health problem resulting from manganese exposure. Manganese is an essential element for good health. It is present in the environment at levels ranging from tenths of a microgram/m^3 in air to thousands of micrograms per gram in rocks and soil. The natural background levels of manganese in water ranges from micrograms per liter to hundreds of micrograms per liter.

Normal dietary intake of manganese is 2,400 µg per day. On the average the body has a manganese content of 12,000 µg. There is a wide margin between these levels where manganese is essential for good health (and is, in fact, required to prevent manganese deficiencies) and the levels at which toxicity occurs. All verified cases of toxicity have been observed only in cases where the individuals have had massive occupational exposures. In these cases, the exposure was inhalation of dust containing manganese in concentration of thousands of micrograms per m^3.

The use of HiTEC 3000 in gasoline will contribute a maximum of 0.0009 µg/m^3 of additional manganese to the current ambient levels. This contribution is one million times below the levels at which serious health concerns arise and will not materially shift ambient levels from their present natural levels.

The Ethyl data clearly demonstrate the benefits and performance of HiTEC 3000 when used in unleaded gasoline.

In the case of any substance, the possibility to conduct additional research is unlimited. In the case of manganese and its effect on the natural processes of the body a multitude of research projects have been conducted since 1970, resulting in over <u>400</u> scientific publications. There will always be questions waiting to be answered. The work of the scientific community will continue to search for these answers. The proposed use of HiTEC 3000 presents an opportunity to ameliorate important aspects of automobile pollution. There is no evidence in this large body of scientific knowledge about the health effects of manganese which justifies rejection of this proposal due to a risk relating to the use of manganese in gasoline.

HiTEC 3000 has been used in Canada in virtually all unleaded fuel for over 10 years. Air monitoring of major Canadian cities shows no measurable increase in manganese levels as a result of using HiTEC 3000 in gasoline. There have been no adverse health effects related to the widespread use of HiTEC 3000 in gasoline in Canada. With such a record of experience, there is no reason to believe that the use of HiTEC 3000 constitutes a health risk to the population of the United States.

The facts clearly show that HiTEC 3000 will not cause a public health concern resulting from the granting of this waiver.

The EPA should grant the Ethyl Corporation waiver request for the use of HiTEC 3000 in gasoline.

BIBLIOGRAPHY

1. Abbott, P.J. 1967. Methylcyclopentadienyl Manganese Tricarbuyl (MMT) in Petral: The Toxicological Issues; The Science of the Total Environment. 67: 247-255.

2. Apgar, J. 1968. Effect of zinc deficiency on parturition of the rat. Amer. J. Physiol. 215: 160-163.

3. Cotzias, G.C. 1958. Manganese in health and disease. Physiol Rev. 38: 503-532.

4. EPA, Health Assessment Document for Manganese EPA 600/8-83-013 F, 1984.

5. EPA, Quality Criteria for Water, 1986, EPA 440/5-86-001.

6. Encyclopedia of Chemical Technology, 3rd Edition, Kirk-Othmer Vol. 14, 1981.

7. Environmental Health Criteria 17 - Manganese World Health Organization 1981.

8. Everson, G.L., L.S. Hurley, and J.F. Geiger. 1959. Manganese deficiency in the guinea pig. J. Nutr, 68: 49-56.

9. Geochemistry and the Environmental Volume II - The Relation of Other Selected Trace Elements to Health & Disease, The National Research Council.

10. Jones, T.S. 1987. Bureau of Mines Minerals Yearbook - Manganese.

11. NIOSH Pocket Guide to Chemical Hazards.

12. Schroeder, H.A. 1970. Manganese. Air Quality Monograph 70-17. American Petroleum Institute, Washington, D.C. 34p.

13. Schroeder, H.A., J.J. Balassa, and I.H. Tipton. 1966. Essential trace metals in man: Manganese, a study in homeostasis. J. Chron. Dis. 19: 545.

14. Sigel, H., A. Sigel. Handbook on Toxicity of Inorganic Compounds.

15. Stokes, et al. 1988. Manganese on the Canadian Environment, Natural Research Council Canada.

16. Sunderman, F.W. Jr., T.J. Lau, P. Menghetti, C. Onkeliny, and N. Becker. 1975. Manganese inhalation of nickel carcinogenesis in rats. Clin. Lab. Sci. 5(4): 316-317.

17. Threshold Limit Values & Biological Exposure Indices for 1989-1990 (American Conference of Governmental Industrial Hygienists).

18. 29CFR 1910.1025 July 1, 1989 Revision, Department of Labor 1 OSHA Regulations.